ANIMAL LIFE IN TORRENTIAL STREAMS[1]

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BY

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(*With one plate and ten text-figures*)

SIR JAGDISH, LADIES AND GENTLEMEN,

The subject which I have the honour to bring before you this evening is that of Animal Life in Torrential Streams. I presume that most of you are familiar with what I mean by torrential streams because they are so abundant in all our hills and especially in those hills where the rainfall is high. Just to refresh your memory I shall take you to the Khasi Hills, which are noted for the heaviest rainfall in the world. ' The average annual rainfall at Cherrapunji, a village on the southern face of the hills, is no less than 458 inches. Enormous though this rainfall is, it is little more than half of the maximum on record. In 1861, 905 inches fell, 366 of which were assigned to July alone. The maximum for a single day was, however, recorded in 1876, when 41 inches of rain fell in 24 hours.'[2] It will not be out of place to point out for the sake of comparison that the average annual rainfall of the city of Lahore is nearly 21 inches, which is approximately half of the actual rainfall recorded on a single day at Cherrapunji. The Cherrapunji plateau is admirably drained, and the water is quickly carried off. The streams in the deep gorges swell immensely during and after a heavy fall of rain. Mr. Oldham,[3] who visited one of the streams in these hills after a heavy and sudden fall of rain, describes the scene thus :—' The water had then arisen only about thirteen feet above the level at which it stood a few days previously ; the rush was tremendous—huge blocks of rock measuring some feet across, were rolled along with an awful crashing, almost as easily as pebbles in an ordinary stream. In one night a block of granite,

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[1] The lecture was illustrated with 39 lantern slides, most of which were prepared either from specimens collected by the author or from sketches and photographs made by Babu D. N. Bagchi in the field under the author's supervision.

[2] Allen, *Assam District Gazetteer*, vol. x, p. 30 (1906).

[3] Oldham, *Mem. Geol. Surv. India*, vol. i, p. 174 (1859).

which I calculated to weigh upwards of 350 tons, was moved for more than 100 yards ; while the torrent was actually turbid with pebbles of some inches in size, suspended almost like mud in the rushing stream.' We have here to consider how animals manage to live under such adverse conditions. Besides the rapidity of the flow of water we find that the only kind of food available consists of algal slime covering stones and rocks, for there is little chance of any other type of vegetation to grow as it is liable to be uprooted and carried away by the strength of the current. Very rarely a growth of moss and of higher plants is found in swift currents. Insect larvæ of various kinds are found in fair abundance in these streams and they form a valuable supply of fish food, but it should not be forgotten that the ultimate source of food is the algal slime. Among other conditions that influence the fauna of hill-streams may be mentioned the abundance of shelter, the clearness and shallowness of water during the non-rainy season and consequently intense light during the day-time and lastly the presence of a large quantity of air dissolved in the water.

To adapt themselves to such a peculiar environment the animals have modified their entire organization. In the case of fishes,[1] for instance, we notice that modifications have taken place in the external form, the scale covering, the fins, the mouth, the lips, the jaws, the eyes, the gill-openings, the air bladder, the skeletal and muscular frame work and lastly we find that special modifications of the skin have occurred in places. I have not enough time this evening to discuss the entire set of adaptations, but with your permission I shall confine myself to the external form of the animals and to the special structures that enable them to withstand the swiftness of the currents.

In 1891, Nikolsky[2] dealt with the correlation between the shape of the body of fishes and the strength of the current of streams, but unfortunately his work is not available in India and I have not been able to consult it. I have, however, made extensive observations on this point and I propose to give you a summary of my views on the subject.

In general, fishes are boat-shaped, adapted for swift progress through water. They are longer than broad or deep and the greatest width is in front of the middle leaving the compressed paddle-like tail as the chief organ of locomotion. We get such forms in the sluggish waters of our rivers in the plains and in tanks and ponds, but at the base of the hills where streams possess rocky beds and water flows with some rapidity, the fishes that are met with are more or less of a cylindrical form and are provided with a strong caudal peduncle and a well developed tail fin. The cylindrical form probably does not present so much surface to the strong flow of water as the usual form of the fish and the muscular tail becomes a great asset for progression in swift currents. As we go higher up

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[1] Hora, *Rec. Ind. Mus.*, xxiv, pp. 33-61 (1922).
[2] Nikolsky *Rev. Soc. Nat. St. Petersb.* pp. 137-139 (1891).

Fig. 1.—*Balitora brucei*, Gray, from Nong-priang Stream below Cherrapunji.

in the hills and study the fish fauna of the torrents, it is found that the form is greatly depressed from above downwards, and in some cases it has become almost leaf-like. The under surface is greatly flattened and has developed adhesive organs for clinging to the rocks in these rapid waters and the tail has become very muscular and whip-like to enable the fish to dart about from one rock to another in swift water. The upper surface has assumed a stream-line form so that it presents less resistance to swift currents.

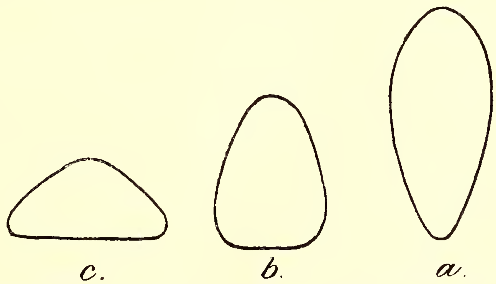

Fig. 2.—Transverse sections of fish showing evolution of form for life in rapid running waters.

(*a*) Section of an ordinary pond fish (*Labeo*).
(*b*) Section of a fish living in moderately swift currents and relatively deeper waters (*Schizothorax*).
(*c*) Section of a typical torrent-inhabiting fish (*Balitora*).

Among fishes I have been able to find two types of adhesive organs,[1] firstly a rounded or elliptical structure with a large callous portion in the centre and a loose membranous flap all round it and secondly an organ composed of grooves and ridges. The former functions as a true sucker by the creation of a vacuum, while the latter in my opinion acts as a mechanical frictional device and prevents the fish from slipping. The true sucker is present in the members of the genus *Garra*, while some sort of a frictional device is present in almost all hill-stream fishes. The latter device possesses one great advantage over the former and it is this:—a vacuum of a certain capacity can have only limited power of adhesion whereas in a frictional device the friction increases with pressure, which under the circumstances is proportional to the rapidity of the flow of water. In streams subject to a sudden rush of water an adhesive apparatus of variable efficiency is very beneficial. Moreover, adhesion by a sucker requires constant exertion on the part of the animal using it, whereas a frictional device acts mechanically, meeting effectively the exigencies of the circumstances.

A powerful sucker occurs in the tadpoles of the section *Rana formosa*. I was afforded an opportunity of testing the efficacy of this mechanism by making a series of observations on the living tadpoles of *Rana afghana* in the Khasi Hills and at Dharmsala in the Kangra Valley. A tadpole was held by its tail and was then placed on a loose piece of stone in water in such a way that its sucker touched the stone. The animal was then lifted out of water by the tail and it was found that the stone was also lifted with the tadpole. By repeating this experiment with stones of different sizes, it was found that a tadpole weighing one-tenth of an ounce could easily, when lifted out of the water, retain a hold on a stone having a weight of about six ounces.

I have here to refer to some very peculiar tadpoles of certain species of the genus *Megalophrys*. Great controversy has raged round the function of the funnel apparatus and a considerable literature has grown round the subject. I made the acquaintance of these tadpoles at Dumpep in the Khasi Hills and found them in abundance in a rapid flowing, rocky stream among weeds and under stones or in crevices in the rocks in sheltered places. To me[2] it at first seemed probable that the two inwardly curved horns of the folded funnel enable the animal to anchor itself among weeds in fairly rapid currents. But further observations carried out in the stream bed itself have convinced me that the peculiar funnel is only a device for gathering plancton on which the animal feeds and that it helps to keep the anterior end buoyant, so that the animal does not knock against rocks if it happens to be swept away by a strong current.

The structural modifications of the fish and of the Batrachian larvae that inhabit our small mountain torrents afford a remarkable instance of parallel evolution or what Annandale and myself [3] have

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[1] Hora, *Rec. Ind. Mus.*, vol. xxv, pp. 587-591 (1923).
[2] *Ibid.*, pp. 585-587 (1923).
[3] Annandale and Hora, *Rec. Ind. Mus.*, xxiv, pp. 505-509 (1922).

called 'communal convergence.' You must have noticed the great similarity in external form and in the structure of the sucker of *Garra* and of the tadpole of *Rana afghana*. In the former we know that these modifications are the results of a series of gradual changes to be observed both in the post-embryonic development, in individual variability and in specific differentiation. In the larvae of *Rana formosa*, however, we know, so to speak, the finished product of evolution in the highly perfected organ of adhesion. In the case of *Garra* at any rate, we have evidence that these changes have resulted, not through mutation or by any Mendelian segregation of characters, but through a gradual accumulation of small changes.[1] The close correlation between these structural changes and differences in the flow of water in which species and even individuals live is at any rate suggestive. Whether in these particular cases we are witnessing the survival of the fittest in the Darwinian sense, which means the evolution of new structures through the agency of small fluctuating variations, or must accept a frankly Lamarckian explanation, which means the evolution of new structures by the constant use or disuse of the parts affected, only experiment can prove.

The Gastropod molluscs that live actually in rapid waters, such as species of *Paludomus*, or which live on rocks at the sides of streams subject to a sudden rush of water, such as *Cremnochonchus syhadrensis*, *Neritina perotettiana*, *Lithotis rupicula* and *Turbinicola saxea*, have solved the problem of existence in their particular habitat by the greatly increased size of the foot and a consequently increased power of attachment. In the case of *Paludomus* the upper whorls are usually worn and the shell comes to resemble the small rounded pebbles among which it usually lives. Among the Gastropod molluscs, however, special mention may be made of the various species of the genus *Ancylus* which inhabit swift currents and are limpet-like in form. They probably stick to stones or other objects by the creation of a sucker in the strict sense of the term. Certain bivalves, such as *Corbicula*, are also found in rapid water, but they manage to live during floods by seeking shelter under rocks or by burrowing in sand. One species of bivalve from the Surma Valley,[2] Assam, has developed this habit to an extraordinary degree. It lives, firmly anchored by its extensive foot, in regular burrows formed either in hard blue clay or in friable sand-stone rocks. It has thus avoided the dangers of swift currents in a most ingenious way. I shall have occasion to refer again later to this mode of life in hill-streams, when dealing with the insect larvae.

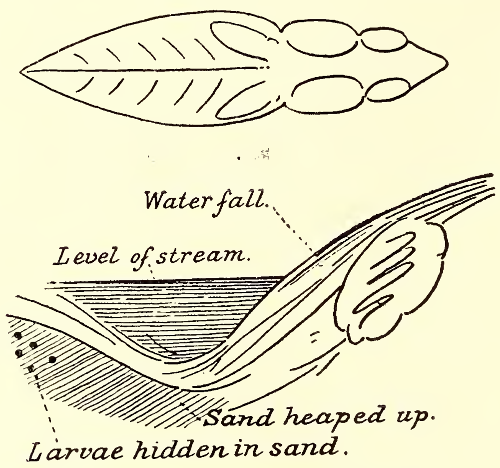
Leeches are also met with in hill-streams but you are probably aware that these animals are provided with well-developed suckers. Those from rapid waters have these suckers better developed. I also found a colony of Polyzoa, or moss-like animals, in rapid water in the Kangra Valley.[3] This is an encrusting form, so that once it is attached to stones it needs no further specialization. The

[1] Hora, *Rec. Ind. Mus.*, xxii, p. 640 (1921).
[2] Hora, *Journ. Aṣiat. Soc., Bengal* (in Press).
[3] *Ibid.*

occurrence of Polyzoa in running water is a rare phenomenon and Annandale observed it only once, in *Plumatella fruiticosa*, in a small jungle stream in Travancore. My specimen from the Kangra Valley also belongs to the same species but it is remarkable that only the form *stricta* of this species occurs in running water, and it seems probable, as Annandale has pointed out, that this form is found only in those places where there is reason to suspect a lack of minute life and, therefore, of food.[1] I have collected a number of Turbellarians or flat worms in hill-streams, but have not so far made a special study of these animals. They are broad, flat and leaf-like and encrust stones and rocks in rapid waters, and Prof. Stanley Gardiner of Cambridge University has very kindly informed me in a private communication that these forms also possess specially modified clinging organs.

Insect larvae of various kinds occur in mountain torrents in large numbers and are remarkably well adapted for life in such situations.[2] I propose to deal with the various groups one by one.

The dragonfly larvae of our torrential streams can be divided into four groups. The first group bury themselves in the sand at the bottom of pools in streams. These are generally found to belong to the Gomphines with a torpedo or stream-line body adapted for pushing forward through sand or facing heavy currents. The legs are



(*From a drawing by Col. Fraser*)

Fig 3.—The form and habitat of Gomphine larvae.

short and adapted for burrowing. These larvae frequent particular spots, usually in front of the foot of a falling column of water, where the water has scoured out the sand and heaped it up down stream. I have illustrated this type by *Macrogomphus wynadicus* and *Megalogomphus hameyngtoni*. The siphon-like tube at the posterior end of

[1] Annandale, *Faun. Brit. India, Freshwater Sponges, Hydrozoa and Polyzoa*, p. 219 (1911).

[2] Musgrave and Campbell, *Austral. Mus. Mag. Sydney*, iii, pp. 28-31 (1927).

the abdomen of the former is the only part of the larva which projects from the sand. These larvae are rectal breathers and hence the utility of such a device is perfectly obvious.

The second group includes limpet-like forms such as *Ictinus* and *Zygonyx* which are actual water-fall dwellers. The belly is absolutely flat and is very broad, the back is highly arched like a limpet and slopes steeply away on either side. They live on rocks and are able to hold their own against the heaviest torrents. It has been believed that adhesion is due to the close application of the ventral plates to a rock and by the creation of vacuum by contraction of the plates. Personally I have no idea as to how far this view may be correct but my examination has revealed the presence of definite adhesive pads on the ventral plates; these pads are very much like the lamellae on the sucker of *Echenei* or the ship holder and are provided with spines, thus forming an efficient frictional device. *Ictinus* and *Zygonyx* belong to widely-separated families but from a similarity of habitat have become modelled alike. The former are Gomphines and the latter Libellulines but the resemblance is so close that an expert might be deceived. These two provide another instance of communal convergence.

The third group comprises root-dwellers and these are found clinging to roots along the river banks, swayed from side to side with every eddy of the current. These are long, thin, attenuated larvae resembling stick-insects. They lie close to the roots and

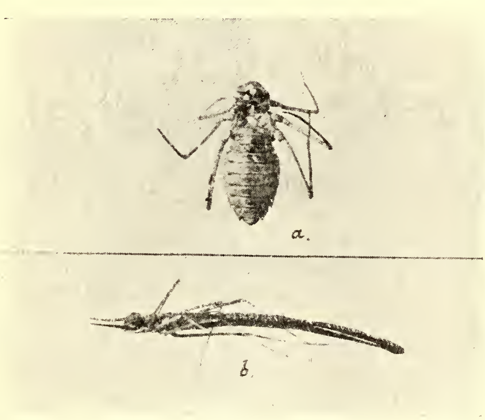


Fig. 4.—Root-dwelling dragonfly larvae of torrential streams.
(*a*) *Macromia ida*, Fraser; (*b*) *Matrona basilaris*, Selys.

thus offer a very small surface to the force of the current. I shall mention here two instances illustrating this group, firstly *Matrona basilaris*, a Calopterygine larva, and secondly the spidery-legged *Macromia ida* a Libelluline larva.

There is yet a fourth group which is found hidden amongst the leafy debris collected in deep pools in the course of mountain streams. These are broad, flat and leaf-like.

I must express here my great indebtedness to Lt.-Col. F. C. Fraser for sending me valuable notes regarding the habits of the fly larvae of hill-streams and for supplying me with specimens for illustrating this lecture.

Among the mayfly nymphs we find adaptations similar to those that I have already shown you in the dragonfly larvae. Here we have burrowing larvae such as those of *Palingenia* and *Polymitarcys;* creeping larvae that anchor themselves on water weeds and stones in swift currents and lastly those larvae that possess flattened bodies. These last are of the *Ecydurus* and the *Heptagenia* type and are usually met with either on the under side of stones in swift current or on the upper sides of rocks in deeper waters. Some of these larvae, both of the clinging type, which are long and thin, and of the flattened type which possess a limpet-like form, frequent bare rocks in very rapid waters. In all these forms very strong claws are developed for grappling on to the rocks and stones, but in certain larvae of the flattened type that frequent the upper sides of rocks in strong currents the tracheal gills are greatly enlarged and are arranged in such a way that a complete or a partial sucker is formed on the under side of the animal when needed. In addition they are provided with a series of pads beset with spines on the under surface of the tracheal gills. A combination of these two devices makes the under surface thoroughly non-slippery. The highest development of the sucker is reached in the nymphs of the archaic genus *Prosopistoma*, which, according to Eaton [1] 'is exceptional in having the body oval in outline, convex above and flattened beneath ; and it possesses the faculty of adhering firmly by suction, like a limpet, to stones.'

The stone-fly nymphs usually occur in situations similar to those of the mayfly larvae of *Ecydurus* and *Heptagenia* types. They are fairly common, but always on the under side of the stones, in such places where water runs swiftly over a bed of comparatively small pebbles. The nymphs cling closely and lie flat with legs outspread ; they hold on by means of stout paired claws that are like grappling hooks. Their legs are flattened and laid down against the stone in such a way that they offer little resistance to the passing current. The efficiency of the claws for grappling can be readily tested by allowing a larva to crawl on the back of one's hand or on one's arm. They are very quick in their movements and are known to be the worst carnivores of torrent fauna.

The larvae of the *Trichoptera* or the so-called caddis-worms are found in all sorts of inland waters. They build a shelter for themselves and drag it along wherever they go. The case or shelter is held fast by the two very powerful, hooked claws at the hinder end. Several of them are found in rapid waters where they have devised several interesting ways to withstand the rush of water. Some fasten their cases to rocks in swift currents by means of their salivary secretion in such a way that a stream-line form is presented to the current and the animal lives with the open end of the case up-stream. The case itself is greatly flattened on the under surface to come

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[1] Eaton, *Trans. Linn. Soc. London. Zoology* (*2*), iii, p. 13 (1888).

in close contact with the support. Some weave a sort of a conical web on the rocks or on water plants growing in swift currents and themselves sit comfortably in its pointed portion and wait for any booty that the current may bring into their web. I have observed

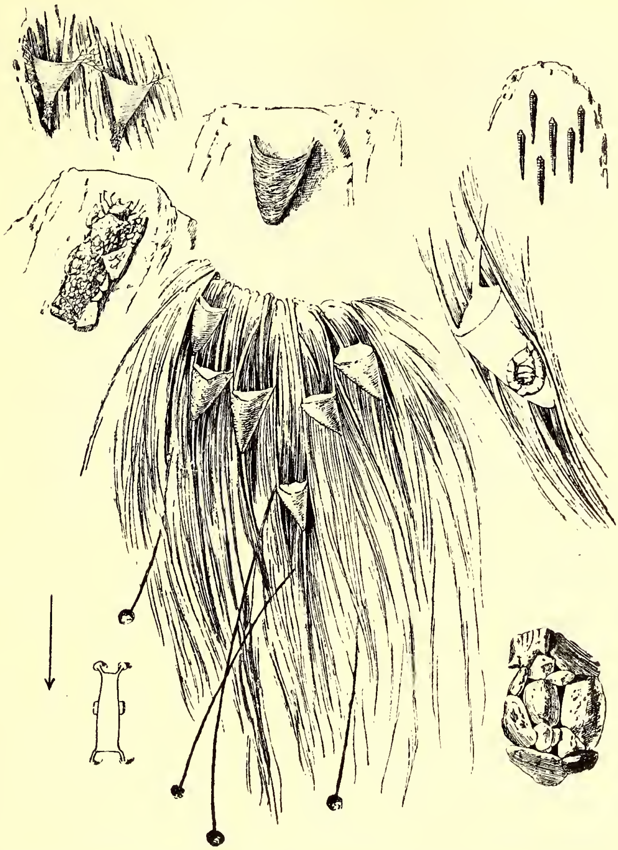

Fig. 5.—Trichopterous larvae (caddis-worms) from torrential streams in India.

certain others that live on the under side of rocks in swift water forming a barricade of small stones and spinning a web over it with a hole for the animal to come out through. Most remarkable among these worms are those in which the case has taken a limpet-like form and the animal is thus enabled to cling fast in very rapid waters.

From among beetles I want to draw your special attention to the remarkable larvae of the genus *Psephenus*, commonly known as 'water-pennies.' They occur in swift streams chiefly on the underside of stones and are known to be especially abundant in the rapids of Niagara, but are by no means uncommon in our Himalayan streams from Darjeeling to the Kangra valley and in the Khasi Hills. They are greatly depressed from above downwards and are almost scale-like in appearance. Their form is either rounded or ovoid. The whole of the under surface of the body appears to act as a sucker and it is very difficult to dislodge these larvae with the fingers.

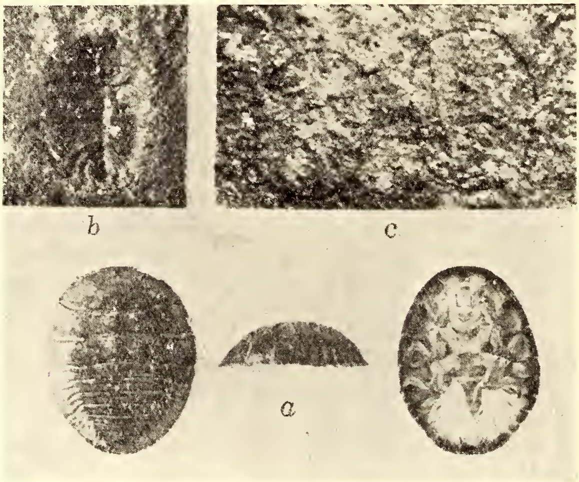

Fig. 6.—*Psephenus* larva and pupa from the Kangra Valley, Punjab.
(*a*) Three views of a larva; (*b*) Pupa soldered on to a rock; (*c*) Scars left on a rock after the pupal skins are washed away.

The pupae are more or less similiar to the larvae, but they are soldered down to the rocks. After the emergence of the beetle, when the pupal skin becomes disintegrated and is washed away, a black oval ring is left to mark the place. The black outline shows the marginal region along which they had been soldered down to the stones. This sort of a permanent adhesion is effected by the secretion of some sticky substance, which leaves black marks on the stones.

The beetles of the family to which *Psephenus* belongs are found for the most part near running water or clinging by means of their strong claws to water plants or other submerged objects. Certain other beetles have also been observed in similar circumstances, but they do not possess any special organs of attachment other than their powerful claws. The under surface is more or less flattened in all beetles, but it is more so in those that frequent rapid waters.

Among the *Diptera*, *Nematocera* or the midge-like flies, there are two remarkable families, whose larvae live on bare rocks in the course of very rapid waters. I here refer to the blood-sucking black-flies (*Simuliidae*) and the net-winged midges (*Blepharsceridae*). A *Simulium* larva is a small bag-shaped, cylindrical creature somewhat broader at the posterior end. It is usually found sticking by its so-called posterior sucker either to water plants that grow in swift currents or to the upper surface of rocks and stones in rapid waters. It hangs from its support with the head pointing

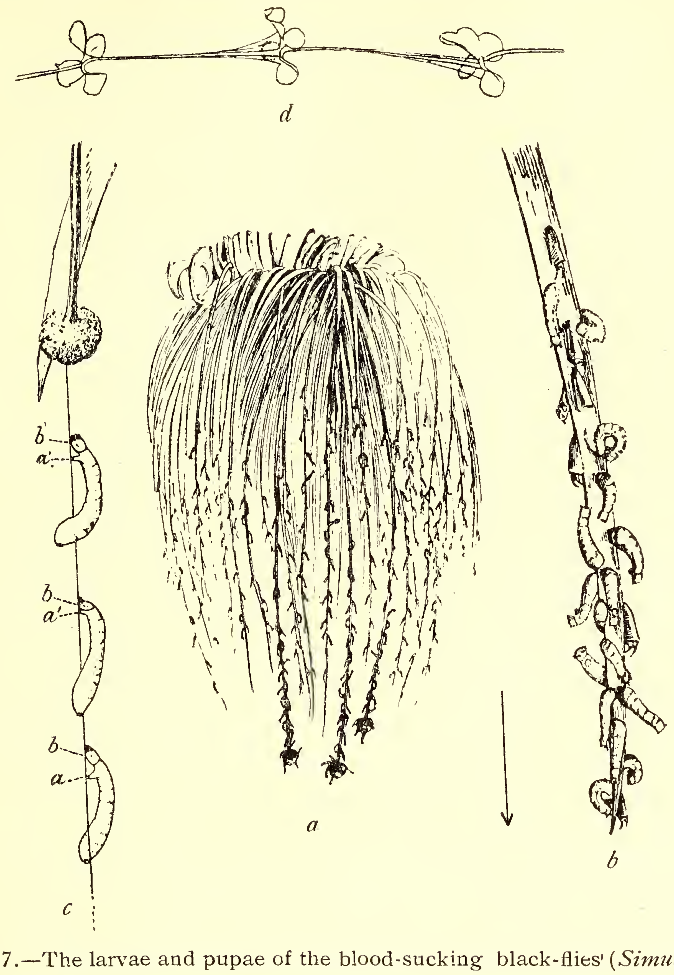

Fig. 7.—The larvae and pupae of the blood-sucking black-flies' (*Simullidae*).

(*a*) Larvae and pupae on water weed (*Eriocaulon miserum*) growing in very swift current. (The artist has not been able to do full justice to the number of larvae that are usually found in similar situations.)

(*b*) A blade of the same weed showing larvae and pupae in various postures.

(*c*) Shows a larva crawling back to its support.

(*d*) A portion of the track left behind by a *Simulium* larvae on a glass slide (highly magnified).

down-stream in such a way that a stream-line form is presented to the current. Its posterior appendage, or the so-called sucker, has received considerable attention. The earlier writers considered it a sucker in the same sense as that found at the posterior end of a leech, but Tonnoir [1] not finding any muscles inserted in the middle of the disc doubted its utility as a sucker. Dr. Puri [2] who has quite recently published a monograph on the structure of these larvae, has found definite muscles and has observed 'that they contract when a larva fixes itself by its posterior end.' He further points out that 'in spite of the presence of these muscles the larva cannot fix itself effectively without the further help of the sticky salivary secretion.' A very close study of the habits of these larvae enables me to say that the posterior appendage does not act as a sucker, and the larva fixes itself with the help of hooks and the salivary secretion alone. The larva spins out this salivary secretion into a fine silk thread which is very sticky and very strong. I have watched a fairly large specimen of a mayfly nymph struggling to free itself from the silk thread of a *Simulium*, and it has been observed time and again that if a larva is disturbed it lets go its hold and is carried away by the current for some distance but all the time it keeps hanging on to its support by a fine silk thread. By means of this rope-way the larva can crawl back to its former support. The consistency of this thread must be very remarkable for it can bear not only the weight of the animal when it presents an inverted stream-line form to the current (for the larva climbs with the head pointing up-stream), but also the tremendous rush of the current at one and the same time. The posterior 'sucker' is provided with a rosette of hooks and the function of these hooks and, therefore, of the 'sucker' is to grip firmly a cluster of silk threads which the animal secretes on the spot where it wants the posterior appendage to be fixed. The necessity for the presence of muscles in connection with this appendage is obvious, for in order to disengage the hooks from the salivary secretion a strong and sudden muscular pull is needed. The muscular action noticed by Dr. Puri at the time of the attachment of the sucker is a manipulation on the part of the animal to enable it to fix its hooks properly in the secretion.

Needham and Lloyd [3] give an interesting account of the general habit of the *Blepharocerid* larvae. They say that though 'Not the most limpet-like but yet the best adapted for hanging on to bare stones in torrents is the curious larva of the net-veined midge, *Blepharocera*, an inhabitant only of clear and rapid streams. The depressed body of this curious little animal is equipped with a row of half a dozen ventral suckers, each of which is capable of powerful and independent attachment to the stones. So important have these suckers become that the major divisions of the body conform to them and not to the original body segments. On these suckers, used as feet, the larva walks over the stones under the swiftest water, foraging in safety where no enemy may follow.' They further observe that 'the naked pupa is found in the same situation and is attached by one strongly flattened side to the

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[1] Tonnoir, *Ann Biol. Lucustre*, xi, pp. 163–172 (1923).
[2] Puri, *Parasitology, Cambridge*, xvii. pp. 311, 312 (1925).
[3] Needham and Lloyd, *Life of Inland Waters*, p. 368 (New York : 1916).

supporting surface.' These larvae are indeed the most highly specialized of all the torrent-inhabiting animals, but in a suitable habitat they are found in countless numbers. I have observed the young larvae in comparatively calm waters either at the side of

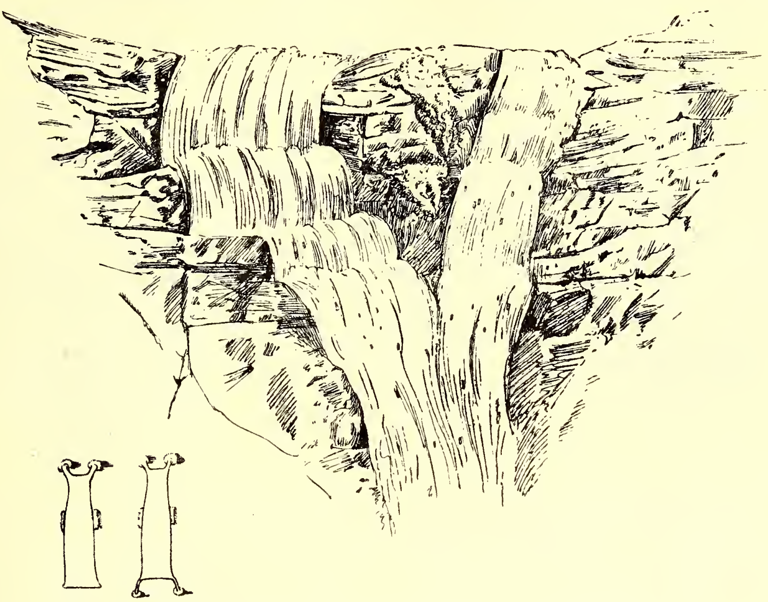


Fig. 8.—Habitat of *Blepharocerid* larvae and caddis-worms.

At the head of the waterfall a large number of larvae of the net-veined midge were found, while on the sides of rocks in the course of the fall were found caddis-worms in their peculiar cases.

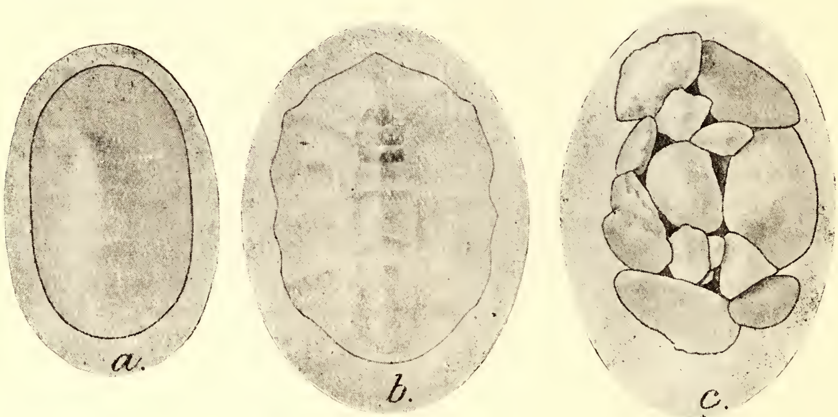
the strong current or actually in places where the current does not run very fast. There appears to be a regular correlation between the stage of growth of a larva and the rapidity of the current in which it lives. The pupæ were also found along with very young larvæ or in small nooks and corners where they were comparatively safe. They usually occurred on vertical rocks over which the water fell and thus kept them moist.

Ladies and gentlemen! You must yourselves have noticed from what I have said, and from what has already been pointed out by Needham and Lloyd,[1] that ' the impress of environment is seen not only in the form of a living animal but also in that of the non-living shelter that it builds. In this there is a parallel of form in the secreted shell on the back of the snail, *Ancylus*, and in the manufactured shell of the back of the caddis-worm, *Helicopsyche*. One would have to search widely to find better examples of the effects of environment in moulding to a common form these representatives of many groups of very diverse structural types. Two of them, at least, were sufficiently like lotic mollusca to have deceived their

[1] Needham and Lloyd, *op. cit.*, p. 374 (1916).

original describers. *Psephenus* was first described as a limpet and *Helicopsyche* as a snail.'

With your permission may I avail myself of this opportunity to thank the successive Directors of the Zoological Survey of India who have given me every possible encouragement and facility to pursue the study of this subject. I am especially



a *b* *c*

Fig. 9.—Showing impress of environment on the form of the non-living shelter.

(*a*) *Ancylus*, a snail; (*b*) and (*c*) cases of two caddis-worms from Pashok in the Darjeeling District.

indebted to Major R. B. Seymour Sewell, who very kindly allowed me to tour in the Kangra Valley, the Khasi Hills and the Darjeeling Himalayas in the course of the last year to check my results gained from the study of the 'lotic' fauna in previous years. It has thus been possible for me to present to you this evening fresh views on the various aspects of the life of the animals that inhabit the swift currents of our torrential streams.

Addendum

In my public lecture I had to content myself with a few typical instances illustrative of adaptations for life in rapid waters. In this note I propose to complete my account of 'Animal Life in Torrential Streams' by citing examples from three other groups of insects whose larvae, pupae or adults frequent swift currents.

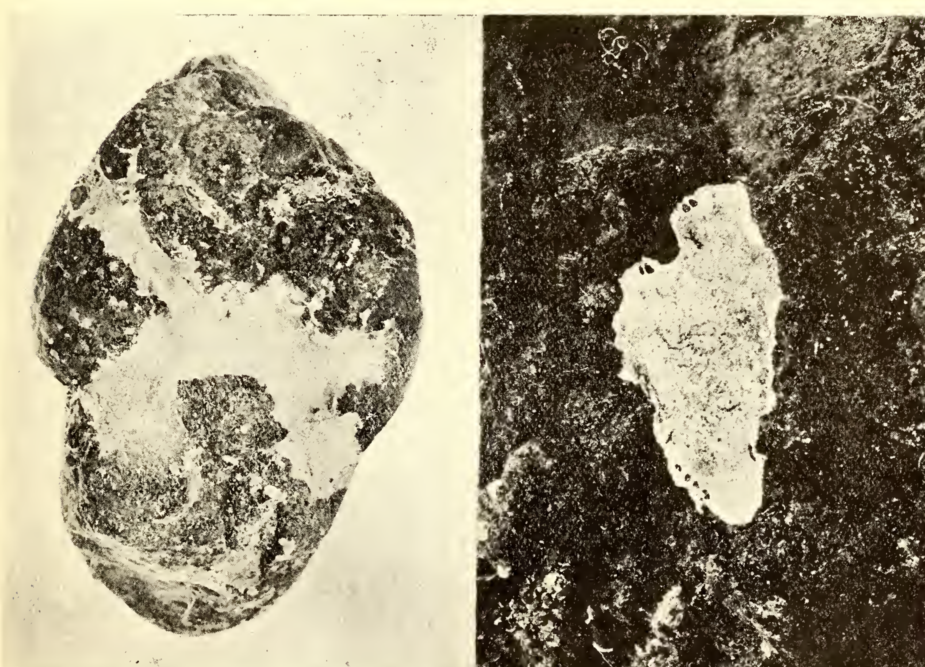
Caterpillars of certain moths of the sub-family *Hydrocampanæ* are known to lead an aquatic existence. Our familiar examples[1] of such larvae are inhabitants of sluggish or stationary waters; they make a shelter out of the leaves on which they feed and which they fasten together by means of silk. In recent years, however, a third type of aquatic larvae has been found in rapid-running streams. In 1908, Muir and Kershaw[2] found caterpillars of *Aulacodes simplicalis*

[1] Miall, *The Natural History of Aquatic Insects*, pp. 226–235 (London) : 1895; Needham and Lloyd, *Life of Inland Waters*, pp. 218–220 (New York : 1916); Imms, *Text Book of Entomology*, p. 492 (1925) ; Needham in Ward and Whipples' *Fresh Water Biology*, p. 903 (New York : 1918).

[2] Muir and Kershaw, *Proc. in Trans. Ent. Soc. London*, pp. xl–xlv (1909).

Snell in a very fast current at Lappa, a mountainous island on the western side of the harbour of Macao in China, and Lloyd[1] has described larvae of *Elophila fulicalis* that live on stones in rapid streams of Ithaca, New York. I have found larvae of similar habit both in the Darjeeling Himalayas, 2 miles below Pashok, and in the head waters of the Nerbadda River. These larvae weave an irregular shelter of thin-spun silk which is attached to a piece of stone at irregular intervals leaving a series of holes for the larva to come out through for the purpose of feeding, etc. Each larva at the time of pupation manufactures a dome-shaped pupal shelter under some portion of the larval cover and this it fastens very carefully to the rock leaving rows of marginal openings on either side for free circulation of water and air through it. When the pupal case is completed the unused portion of the larval shelter is washed away. The pupal case shows a remarkable similarity to the limpet-like non-living shelters to which I have referred to already.

On reference to the Museum Collection I have found similar caterpillars collected by Dr. F. H. Gravely at Hoshangabad and Pachmarhi in the Central Provinces and provisionally referred to the genus *Aulacodes*. Dr. B. Chopra collected a number of these larvae at Kurseong in the Darjeeling Himalayas. All these are



a *b*

Fig. 10.—Larval and pupal shelters of a Pyralid moth.
(*a*) Larval shelter; (*b*) Pupal case.

[1] Lloyd, *New York Journ. Ent. Soc.*, xxii, pp. 145-152, pp. iii, iv (1914).

flattened from above downwards and are provided with branchial filaments for aquatic respiration.

Drs B. Chopra and H. S. Rao have drawn my attention to certain creeping Water-Bugs (Family *Naucoridæ*) recently collected by them in Burma from underneath stones in swift currents. These insects are flat-bodied and are oval in outline. The femora of the front legs are greatly enlarged and are fitted for grasping, while the middle and hind legs are suited for crawling about. The under surface of each half of the posterior segments is provided with a group of strong spines, which probably act as adhesive pads in the same way as the spines on the sucker of *Echeneis*.

Neuropterous larvae of various kinds are found in swift currents, but they are not by any means specially modified for such an existence. They live under stones and are not affected by the rapidity of the current. Several other kinds of beetle and dipterous larvae are found under stones and are not modified for stemming the swiftness of a current except for the fact that they possess very strong claws.

I want to express here my great indebtedness to Mr. S. Ribeiro for the valuable assistance he has rendered to me in sorting out my insect material and in looking up references for me on various points.